Announcements

Homework for tomorrow…

Ch. 33: CQ 3, Probs. 4, 6, & 27

32.38: 0.28 Am^2

32.39: a) 1.3×10^{-11} Nm b) 90^o CW rotation

32.63: 2.4×10^{10} m/s^2 , up

- Office hours…

  MW 10-11 am

  TR 9-10 am

  F 12-1 pm

- Tutorial Learning Center (TLC) hours:

  MTWR 8-6 pm

  F 8-11 am, 2-5 pm

  Su 1-5 pm

Chapter 33

Electromagnetic Induction

(*Motional emf & Magnetic Flux*)

Last time…

Motional emf for a conductor moving with velocity v *perpendicular* to the B-field…

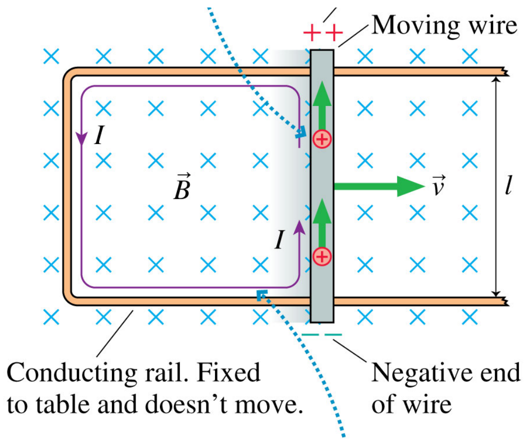
$$\boxed{\mathcal{E} = vlB}$$

The *induced current* in the circuit….

$$\boxed{I = \frac{vlB}{R}}$$

The *force* required to pull the wire with a constant speed v…

$$\boxed{F_{pull} = F_{mag} = \frac{vl^2B^2}{R}}$$



Last time…

The *rate* at which *work is done* on the circuit *exactly equals* the *rate* at which *energy is dissipated*.

$$\boxed{P_{input} = P_{dis} = \frac{v^2 l^2 B^2}{R}}$$

Summary:

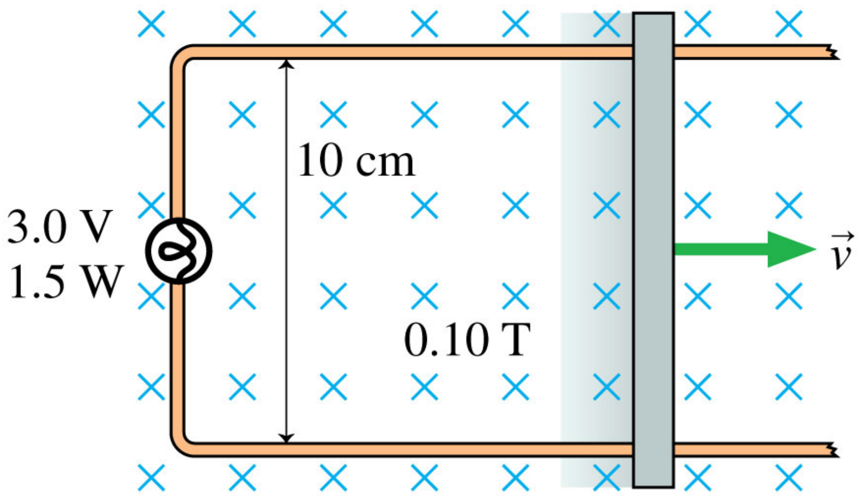
1. Pulling or pushing the wire through the *B*-field at speed *v* creates a *motional emf* in the wire, which *induces a current* in the circuit.
2. To keep the wire moving at *constant* speed, a *pulling or pushing force* must balance the *magnetic force* on the wire. This force does work on the circuit.
3. The work done by the pulling or pushing force *exactly balances* the energy dissipated by the current as it passes through the resistance of the circuit.

i.e. 33.3
Lighting a bulb

The figure below shows a circuit consisting of a flashlight bulb, rated 3.0 V/1.5 W, and ideal wires with no resistance. The right wire of the circuit, which is 10 cm long, is pulled at a constant speed v through a perpendicular B-field of strength 0.10 T.

What *speed* must the wire have to light the bulb to full brightness?

What *force* is needed to keep the wire moving?



$\Delta V = 3.0V$

$P = 1.5w$

$l = 0.10m$

$B = 0.10T$

$I = \frac{vlB}{R}$

$v = \frac{IR}{lB}$

$F = \frac{vl^2B^2}{R}$

$P_r = I\Delta V$

$I = \frac{P_r}{\Delta V} = \frac{1.5w}{3.0V} = 0.5A$

$R = \frac{\Delta V}{I} = \frac{3.0V}{0.5A} = 6\Omega$

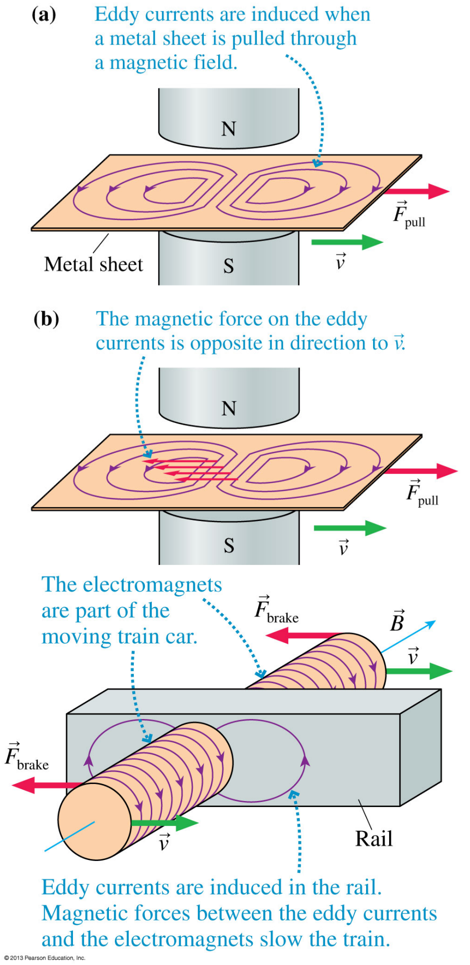
$v = \frac{0.5A(6\Omega)}{(0.10m)(0.10T)}$

$v = 300m/s$

$F = \frac{(300m/s)(0.1m)^2(0.1T)^2}{6\Omega}$

$F = 5.0\times10^{-3}N$

Eddy Currents

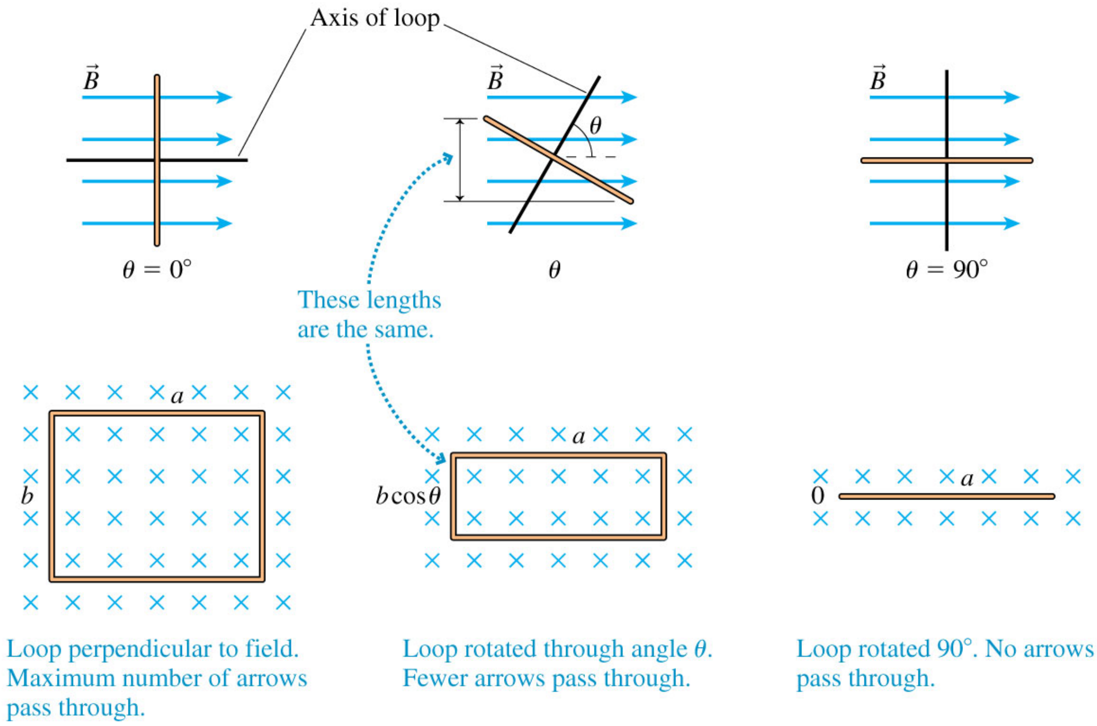


- Consider pulling a *sheet* of metal through a *B*-field.
- Two "whirlpools" of current begin to circulate in the solid metal, called *eddy currents*.
- The magnetic force on the eddy currents is a *retarding force*.
  - form of *magnetic braking*.

33.3: Magnetic Flux

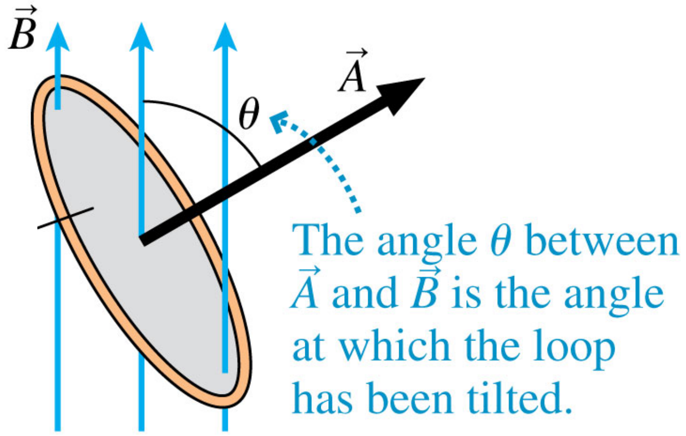
Faraday found that a current is *induced* when the *amount of B-field passing through a coil or loop* of wire *changes*..

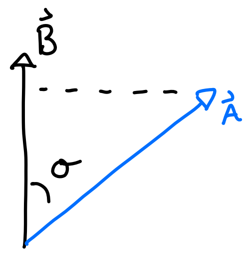
- What exactly is "*amount of B-field passing through a loop*" ?



33.3: Magnetic Flux

What is the *magnetic flux*, Φ_m, passing through a loop?





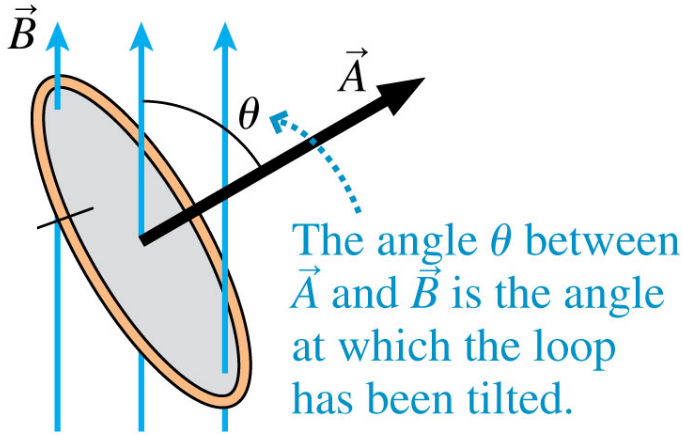
Define the *area vector*, $\vec{A}$, ...

Magnitude: Area A of the loop

Direction: perpendicular to the loop

33.3: Magnetic Flux

What is the *magnetic flux*, Φ_m , passing through a loop?



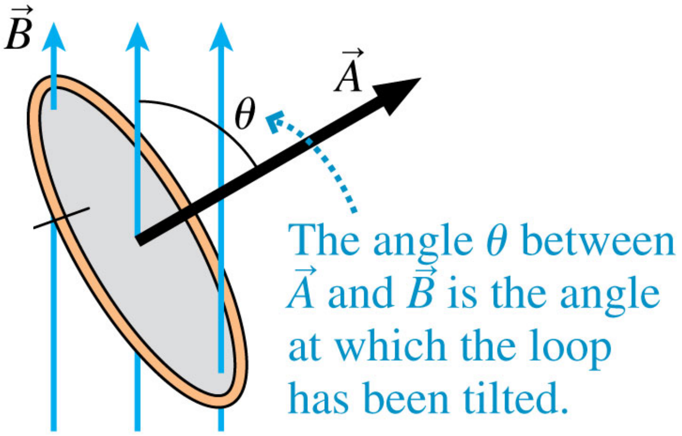
$$\boxed{\Phi_m = BA\cos\theta}$$

SI Units?

$$[\Phi_m] = T\ m^2 = Wb$$ “Weber”

33.3: Magnetic Flux

What is the *magnetic flux*, Φ_m, passing through a loop?



$$\boxed{\Phi_m = BA\cos\theta}$$

or

$$\boxed{\Phi_m = \vec{B}\cdot\vec{A}}$$

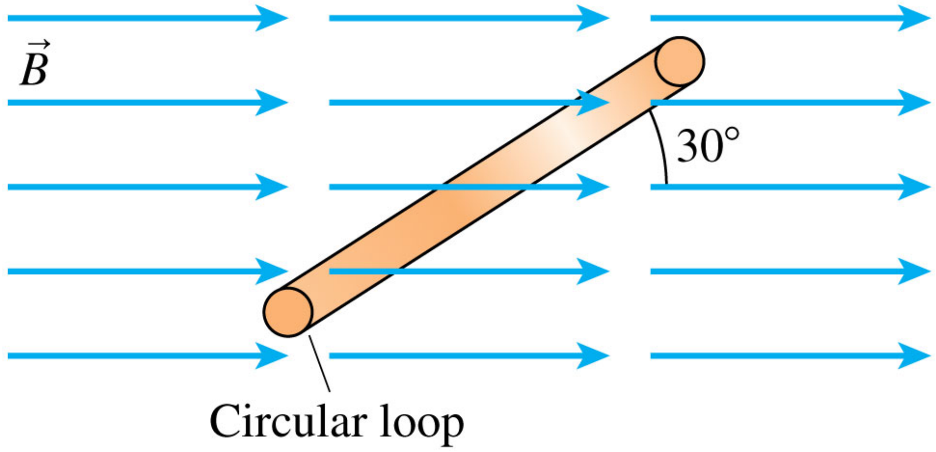
SI Units?

$$[\Phi_m] = T\ m^2 = Wb$$ "Weber"

i.e. 33.4:
A circular loop in a *B*-field

The figure below is an edge view of a 10 cm diameter circular loop in a uniform 0.050 T magnetic field.

What is the magnetic flux through the loop?



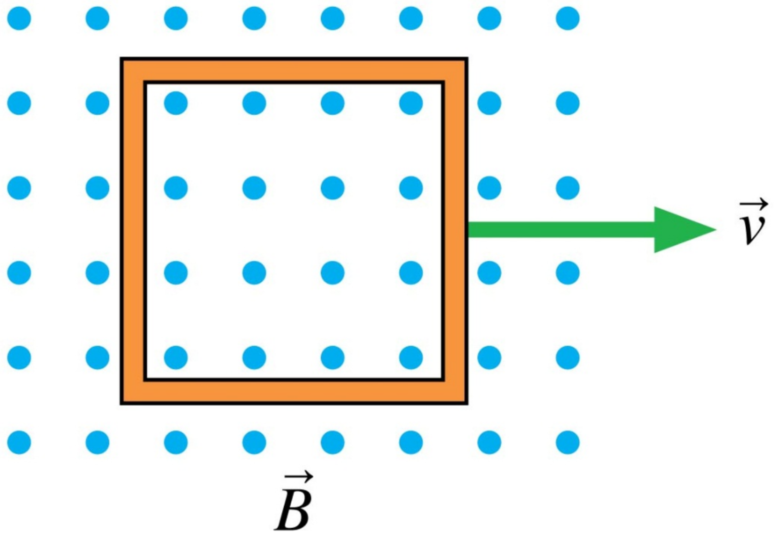
$B = 0.05T$
$A = \pi(5.0\times10^{-2}m)^2$
$\theta = 60^\circ$

$BA\cos\theta$

$\phi = (0.05T)(\pi(5.0\times10^{-2}m))^2\cos 60$
$\phi = 2.0\times10^{-4}$ wb

Quiz Question 1

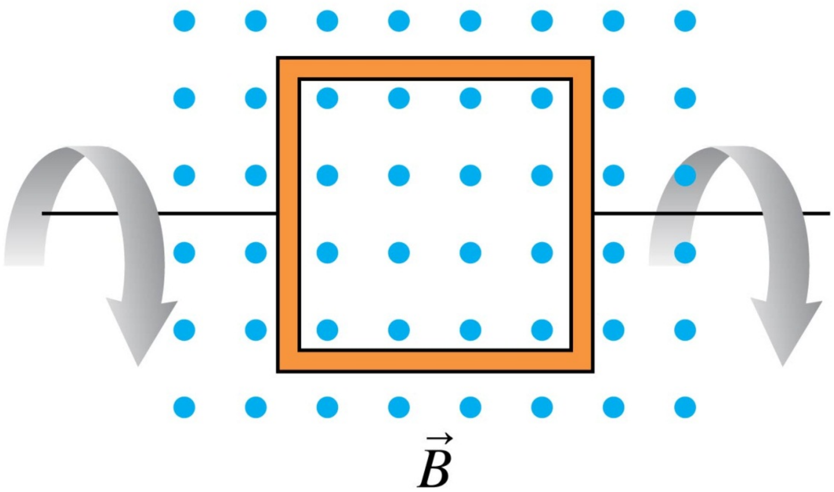
The metal loop is being pulled through a *uniform* B-field. Is the magnetic flux through the loop changing?



1. Yes.
2. No.

Quiz Question 2

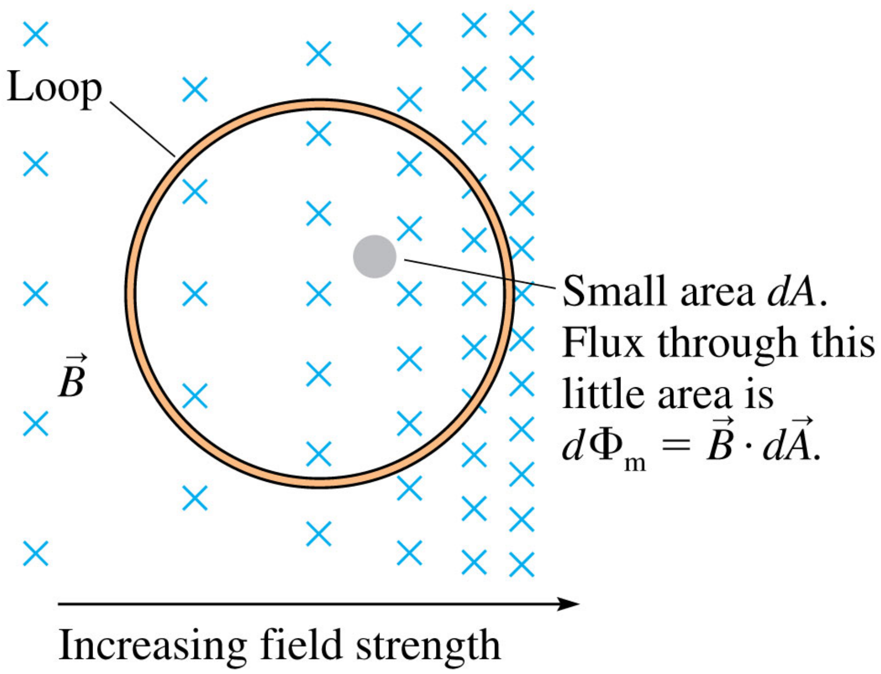
The metal loop is rotating in a *uniform* B-field.
Is the magnetic flux through the loop changing?



1. Yes.
2. No.

Magnetic Flux in a *non-uniform* field

What is the *magnetic flux*, Φ_m , passing through the loop in the *non-uniform B-field*?

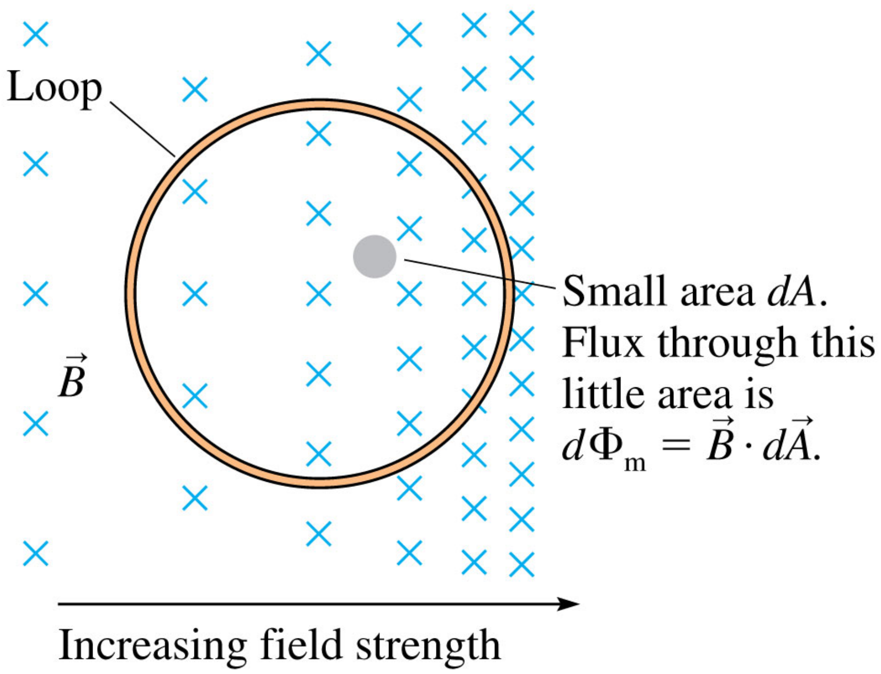


$$d\Phi_m = \vec{B} \cdot d\vec{A}$$

$$\Phi_m = \int \vec{B} \cdot d\vec{A}$$

Magnetic Flux in a *non-uniform* field

What is the *magnetic flux*, Φ_m , passing through the loop in the *non-uniform B-field*?



$$\Phi_m = \int \vec{B} \cdot d\vec{A}$$

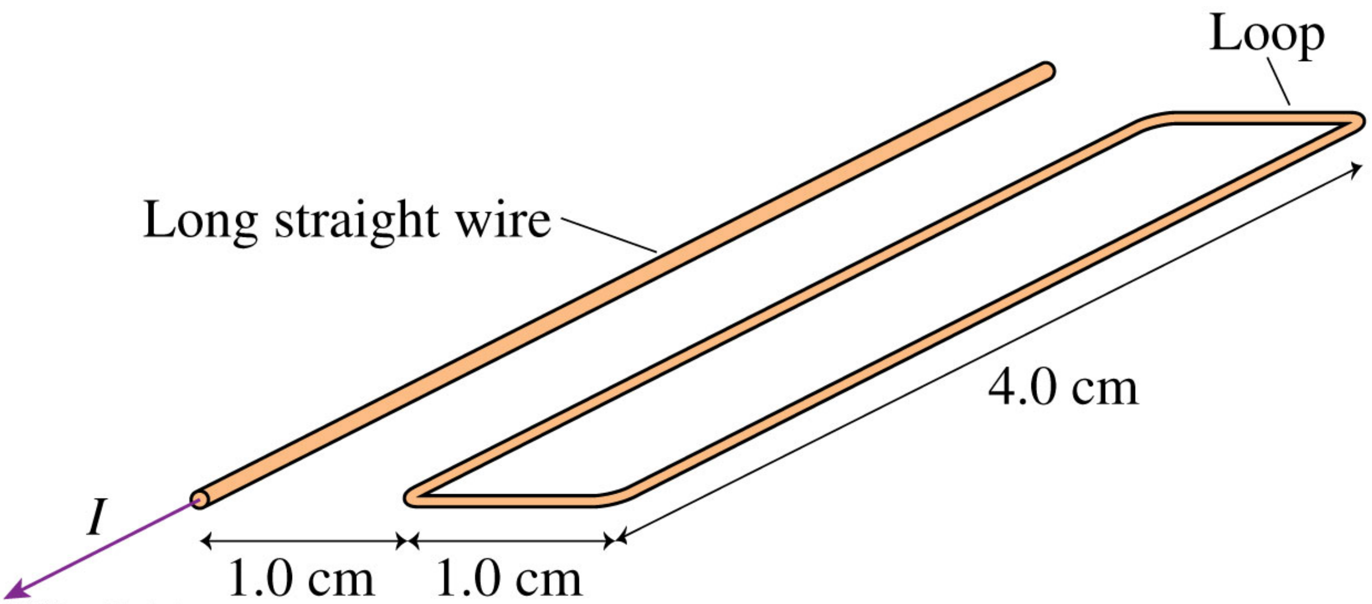
Notice:

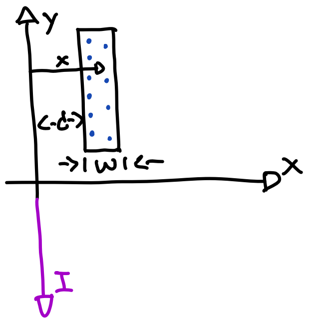
The integral is over the *area of the loop*.

i.e. 33.5: Magnetic flux from the current in a long straight wire

The 1.0 cm x 4.0 cm rectangular loop of the figure below is 1.0 cm away from a long straight wire. The wire carries a current of 1.0 A.

What is the magnetic flux through the loop?





$B = \frac{\mu_0 I}{2\pi}$ $\quad dA = \ell\, dx$

$$\vec{B}\cdot d\vec{A} = B\,dA = \frac{\mu_0 I \ell}{2\pi}\frac{dx}{x}$$

Total magnetic Flux

$$\Phi_m = \int \vec{B}\cdot d\vec{A} = \int_d^{d+w} \frac{\mu_0 I \ell}{2\pi}\frac{dx}{x}$$

$$\frac{\mu_0 I \ell}{2\pi}\int_d^{d+w}\frac{dx}{x}$$

$$\frac{\mu_0 I \ell}{2\pi}\ln(x)\Big|_d^{d+w}$$

$$\frac{\mu_0 I \ell}{2\pi}\left(\ln(d+w) - \ln(d)\right)$$

$$\frac{\mu_0 I \ell}{2\pi}\ln\left(\frac{d+w}{d}\right)$$